EDGEWOOD
CHEMICAL BIOLOGICAL CENTER
U.S. ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND

ECBC-TR-389

DOMESTIC PREPAREDNESS: SARIN VAPOR CHALLENGE AND CORN OIL PROTECTION FACTOR (PF) TESTING OF THE CB40 CNR FULL FACE RESPIRATOR

Lee E. Campbell
Raymond R. Lins

RESEARCH AND TECHNOLOGY DIRECTORATE

Alex G. Pappas
Adam D. Seiple

ENGINEERING DIRECTORATE

July 2004

ABERDEEN PROVING GROUND, MD 21010-5424

Disclaimer

The findings in this report are not to be construed as an official Department of the Army position unless so designated by other authorizing documents.

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. REPORT DATE (DD-MM-YYYY)	2. REPORT TYPE	3. DATES COVERED (From - To)
XX-07-2004	Final	Jul 2002 - Sep 2002

4. TITLE AND SUBTITLE
Domestic Preparedness: Sarin Vapor Challenge and Corn Oil Protection Factor (PF) Testing of the CB40 CNR Full Face Respirator

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

6. AUTHOR(S)
Campbell, Lee E.; Lins, Raymond R.; Pappas, Alex G.; and Seiple Adam D.

5d. PROJECT NUMBER
None

5e. TASK NUMBER

5f. WORK UNIT NUMBER

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) AND ADDRESS(ES)
DIR, ECBC, ATTN: AMSRD-ECB-RT-AE/AMSRD-ECB-ENE-M, APG, MD 21010-5424

8. PERFORMING ORGANIZATION REPORT NUMBER
ECBC-TR-389

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)
DIR, ECBC, ATTN: AMSRD-ECB-ENH, APG, MD 21010-5424

10. SPONSOR/MONITOR'S ACRONYM(S)

11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT
Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

Results of performance testing of the CB40 CNR Air Purifying Full Face Respirator are described. Three series of tests were performed: (1) breakthrough time determinations of cartridges/canisters against sarin (GB), (2) GB vapor breakthrough determination of entire system using manikin headform and simulated breathing, and (3) corn-oil protection factor determinations of system using human subjects. Results indicate that canisters provide adequate resistance to GB breakthrough against high-concentration challenges, and that corn oil aerosol and high-concentration GB vapor penetration into the breathing zone of the respirator occur at acceptable levels.

15. SUBJECT TERMS

Corn Oil	Respirator	Protection Factor (PF) Testing	Sarin-Challenge Testing
Aerosol	Cartridge/Canister	Chemical Agent Breakthrough Testing	GB

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Sandra J. Johnson
U	U	U	UL	25	19b. TELEPHONE NUMBER (include area code) (410) 436-2914

Blank

EXECUTIVE SUMMARY

When the nature or concentration of a potential chemical threat either has not been or cannot be determined, NIOSH guidelines are that responders must wear self contained breathing apparatus (SCBA). The SCBA has an integral air supply that normally will suffice for 30- or 60- min, and the air tank can be changed out, if necessary. When concentrations have been determined to be a lower threat level, other types of protection may be used, such as negative pressure air purifying respirators (APR) that have been found to be protective against chemical warfare (CW) agents. This report contains test results of one commercial APR that was tested against CW agent GB vapor, and the PF determined by the Army standard method. The GB challenge used (200 mg/m^3) is much higher than this type of mask is allowed to be worn in.

The PF testing uses liquid aerosol challenges; this test indicates the effectiveness of the respirator against biological threats, which are sub-micron size particles. The canisters used with this respirator were also challenged separately with GB vapor for 1 hr. No penetration of GB was detected through any of the 22 canisters tested. The three respirator systems (facepiece plus canister) tested for 1- or 3- hr (two each) did not show presence of GB inside the facepiece. These results indicate that this respirator may resist permeation-penetration by low concentrations of GB vapor for up to 3 hr. The PF results indicate that this respirator will provide good resistance to inward leakage of aerosols, but it is possible that unless care is taken, the tight seal around the face may be broken because of physical activity. This also must be considered in the case of vapor leakage, since it is possible to produce a tight seal on a manikin before testing and maintain it during testing. It is necessary that users of tight-fitting respirators be fit tested before using the respirator and periodically afterwards.

Blank

PREFACE

The work described in this report was authorized under the Expert Assistance (Equipment Test) Program for the U.S. Army Edgewood Chemical Biological Center (ECBC) Homeland Defense Business Unit. This work was started in July 2002 and completed in September 2002.

The use of either trade or manufacturers' names in this report does not constitute an official endorsement of any commercial products. This report may not be cited for purposes of advertisement.

This report has been approved for public release. Registered users should request additional copies from the Defense Technical Information Center; unregistered users should direct such requests to the National Technical Information Service.

Blank

CONTENTS

FIGURE

TABLES

DOMESTIC PREPAREDNESS: SARIN VAPOR CHALLENGE AND CORN OIL PROTECTION FACTOR (PF) TESTING OF THE CB40 CNR FULL FACE RESPIRATOR

1. INTRODUCTION

In 1996, Congress passed Public Law 104-201 (Defense Against Weapons of Mass Destruction Act of 1996), directing the Department of Defense (DoD) to assist other federal, state, and local agencies in enhancing preparedness for terrorist attacks using weapons of mass destruction. The DoD responded by forming the Domestic Preparedness (DP) Program that same year. One of the objectives of the Domestic Preparedness Program is to enhance federal, state and local emergency and hazardous material (HAZMAT) response to nuclear, biological and chemical (NBC) terrorism incidents. As part of an effective response, emergency and HAZMAT personnel who are responding to an incident will use personal protective equipment (PPE) to protect them from exposure to chemical agents or biological agents. The specific PPE that would be used by these federal, state and local emergency and HAZMAT personnel would depend upon the situation encountered and what PPE is held in inventory. In some cases, commercial respirator systems with canisters/cartridges may be used to enter a contaminated or potentially contaminated area if the respirators have been tested against the contaminant.

This program tasked the U.S. Army Edgewood Chemical Biological Center (ECBC) of the U.S. Army Soldier and Biological Chemical Command (SBCCOM)* to perform chemical agent and protection factor testing of commercial respirator systems and canisters/cartridges. The respirator is designated CB40 CNR (Chloroprene/Natural Rubber) Full Face Respirator with the ITL/C2A1/FR First Responder Canister. This item is manufactured by CREATEC Consulting LLC (Bransford, CT).

For this phase of the program one type of air-purifying negative pressure respirator (NPR) with tight-fitting facepiece was tested with CW agent Sarin (GB) vapor, and also with corn oil aerosol. The objectives were to determine the protective potential of the CB40 against Sarin vapor; to determine the adsorptive efficiency of the ITL/C2A1/FR canister; and to determine the overall protection factor (PF) using the standard Army corn oil aerosol test with human subjects. Another objective was to assist potential users in assessing the suitability of this respirator for use in a potential GB threat situation. The concentration of GB employed in these tests (200 mg/m^3) is extremely high, as such a real-life threat would require use of SCBA protection. However, the test results from such a high challenge concentration can be indicative of the protection against a much lower concentration in which the respirator might be used. The CB40 Respirator is shown in the Figure.

* Now known as the U.S. Army Research, Development and Engineering Center (RDECOM).

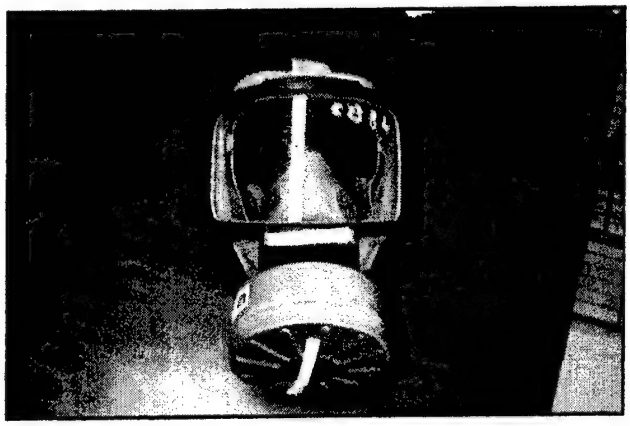

Figure. CB40 CNR Full Face Respirator

2. CHEMICAL AGENT TESTING

2.1 Chemical Agent Testing Equipment.

2.1.1 Vapor Generator.

GB vapors were generated by using a syringe pump that injected liquid GB into a heated tee in the air dilution line. The rate of injection was such that the concentration was controlled to that specified in the test plan. The GB vaporized in the heated tee, was carried by the dilution air into the mixing chamber, thence into the exposure chamber. An Ambient Air Analyzer, (MIRAN model 1A) was used to monitor the concentration in the test chamber during the test. The MIRAN is an infrared radiation detector that uses a long pathlength cell through which the agent-air mixture passes.

2.1.2 Negative Pressure Respirator (NPR) Test Chamber.

The test chamber for the NPRs was a Plexiglas box approximately two feet on a side with a removable front panel and four legs on the bottom about four inches long, which allowed air to flow under the chamber when it was located inside a fume hood. A test fixture, called SMARTMAN (SiMulant Agent Resistant Test MANikin), which is a human head form, medium size, with a movable face piece and an inflatable peripheral seal, was attached to the floor of the chamber. The mouth orifice of the head form was connected by a large tube to a breather pump; there were also two sampling tubes in the nose, one in the eye, and one in the forehead. All these tubes pass down through the interior of the head form, down through the floor of the chamber, and connect to remote detectors, the breather pump, or other monitoring devices, such as pressure gauges. Because agent-air mixture passes through the test chamber during the test, the outlet ports on top of the chamber are covered by military M12A1 filters to scrub agent from the air passing through. Other ports in the chamber walls are used to introduce the agent challenge into the chamber, to attach pressure gauges for monitoring pressure, to introduce liquid aerosol for preliminary leak testing of an installed respirator, or to monitor the agent concentration inside the chamber.

2.1.3 Cartridge/Canister Test Chamber.

The test chamber for the canister comprises two parts, the base plate and the cover. Both parts are machined from stainless steel. The assembled chamber is a closed cylinder. The base plate has a raised portion and a somewhat wider rim; when the cover is in place the bottom of the cover rests on the rim while the raised portion of the base plate seals against the inside of the cover by means of O-rings. In the center of the base are an orifice and an adapter machined to accommodate a North Atlantic Treaty Organization (NATO) canister thread. Another orifice is offset from the center and is machined with pipe threads; agent challenge is introduced into the chamber by this means. The chamber, when closed, accommodates a canister up to the size of a C2A1. The center orifice is connected by a line outside the chamber to a vacuum source of a breather pump in order to pull the agent challenge through the chamber. A rotameter and a scrubber filter are placed in this line; there is also a connection between the rotameter and the test chamber for a detector (MINICAMS®) used to monitor GB agent breakthrough.

2.1.4 Breather Pump.

The Military Breather Pump E1R1 (Jaeco Fluid Systems, Inc, Exton, PA) was used to simulate breathing through the respirator. This is a reciprocating pump that produces a sinusoidal breathing pattern by means of a reduction planetary gear system that incorporates a Scotch Yoke. With each piston stroke the flow rate starts at 0 L/min, rises to a peak flow midway through the stroke and falls back to zero at the end of the stroke. During the initial stroke, air is pulled from the test chamber through the respirator (including the canister/cartridge); on the return stroke this air is exhausted through the exhalation valve of the respirator. The two pump strokes, forward and reverse, produce a complete sine wave pattern. The peak flow produced by this pump is approximately pi times the minute volume. The minute volume (liters pumped in 1 min) and the number of strokes per minute (breaths) can be adjusted on this pump.

2.1.5 GB Detector.

A MINICAMS® was used as a GB breakthrough detector. This instrument is a gas chromatograph that samples air through a preconcentrator tube. The tube contains an adsorbent material that traps the agent for a set time, then the tube is heated to desorb the agent onto the chromatograph column, thence into the detector (flame photometric detector). The MINICAMS® is manufactured by OI Analytical, Birmingham, AL.

2.1.6 Aerosol Leak Detector.

The leak detector, TDA-99M, generates a liquid aerosol from Emery 3004 polyalphaolefin. The aerosol particle size range is 0.1 - 1.0 μ, at a concentration of 100 mg/m^3. The aerosol is directed by a hollow wand to selected areas of the respirator, or it fills the closed chamber, while the breather pump is operating. The TDA-99M samples air inside the respirator and determines if any aerosols are present, then calculates the percent penetration. The TDA-99M is manufactured by Air Techniques, Inc. (Baltimore, MD).

2.2 Chemical Agent Testing Methods.

2.2.1 Respirators.

Because it would be prohibitively expensive to test a statistically significant number of respirators against GB, only three items were tested. The challenge concentration used was extremely high, so that if breakthroughs occurred they would be more easily detected. The results, then, are merely indicative of the actual performance of the respirator. The breakthrough concentration listed for the respirators and the cartridges/canisters is the 8-hr time weighted average (TWA) concentration for GB for an unmasked worker. The respirator system, including an attached canister or cartridge, was mounted on the SMARTMAN by tightening the straps of the harness. The peripheral seal was inflated (3-5 psig) to form a seal against the inside of the face piece of the respirator.

Before an agent test was started, an aerosol leakage test was performed, using the TDA-99M Aerosol Leak Tester. The detector section of the tester was connected to one of the SMARTMAN nose sampling ports inside the respirator, and the aerosol was directed against the respirator through a wand. The breather pump was turned on during the leak test. If no leak was detected, then the chamber was closed and the aerosol was injected into the test chamber to test the entire respirator at once. If an aerosol leak was detected, the leak path was found and corrected. If there was no leak, the agent test was performed. For the GB test, a MINICAMS® detector was connected to one of the SMARTMAN nose sampling ports to monitor for the presence of GB inside the respirator. The GB challenge, generated as described above, was passed from the mixing chamber into the NPR test chamber. The conditions used for testing are listed in Table 1.

Table 1. Conditions for Testing Respirators

Rate of air flow through exposure chamber	50 L/min
Concentration of challenge GB	200 mg/m^3
Breakthrough concentration limit	0.0001 mg/m^3
Total test time if breakthrough is not observed	60 min or 3 hr
Precondition of cartridge/canister	25 °C/50% RH/6 hr
Temperature of test chamber	25 ± 3 °C
Flow rate of breather pump	25 L/min
Pump strokes per minute	25
Volume per breath	1 L

2.2.2 Canisters.

The canisters were tested separately to establish their performance against a GB vapor challenge. A total of 22 canisters was tested. This number represents 90% reliability at 90% confidence level when no failures occur amongst the 22 items tested. A failure was defined as detection of agent through the canister before the end of the test period, in this case, 1 hr.

The canisters were preconditioned at 50% relative humidity (RH) and 25 °C for 6 hr before agent testing. The purpose of the preconditioning was to establish a uniform level of moisture on the adsorbent similar to what might be encountered in use; excessive moisture could adversely affect the adsorption of GB.

Testing the canisters alone allows one to infer, when a system failure occurs, whether the reason is the respirator or the canister. Each canister was tested for 60 min, a nominal time that indicates whether the canister gas life will be much greater than the time the respirator will be used. The test conditions are listed in Table 2.

Table 2. Conditions for Testing Canisters

GB challenge concentration	200 mg/m^3
Flow rate, NPR canisters	25 L/min
Breakthrough concentration	0.0001 mg/m^3
Test time if breakthrough is not observed	1 hr
Precondition of cartridge/canister	25 °C/50% RH/6 hr
Temperature of test chamber	25 ± 3 °C
Relative humidity of test air	50 ± 5%

2.3 Chemical Agent Test Results and Discussions.

2.3.1 Full Respirator on Head Form.

One of the respirators was tested for a period of 1 hr; the other two were tested for 3 hr. No GB was detected inside any of the three respirators during the 1- or 3-hr test periods. These results indicate the probable performance of the respirators in an environment of much lower concentrations of GB vapor.

2.3.2 Canisters.

The canisters were tested for 1 hr. No detectable GB penetrated any of the 22 canisters; the detection limit for GB is 0.05 mg/m^3.

3. PROTECTION FACTOR (PF) TESTING

The respirators were tested for performance to be compared with the standard U.S. Army Protection Factors (PF) using human subjects and corn oil aerosols. Anthropometrical data for each of the volunteers is listed in the Appendix. Volunteers entered a test chamber containing a uniformly distributed concentration of corn oil aerosol. The inside of the oronasal region of the mask was connected by a sampling tube to a laser photometer that determined the concentration of aerosol inside the mask and compared it with the concentration in the test chamber. The volunteers performed a series of exercises, and the concentration of aerosols

inside the respirator was determined during each exercise. The ratio of the aerosol concentration outside the respirator to that inside the mask was used to calculate a PF during each exercise (PF_i), and an overall PF (PF_o) was calculated. This is shown in the raw data of Table 3.

3.1 Test Facilities and Setup.

A challenge aerosol concentration of 20 - 40 mg/m³, polydispersed corn oil aerosol having a mass median aerodynamic diameter (MMAD) of 0.4 - 0.6 μ (the Army Standard, representing biological warfare agents) was generated in a 10-ft × 20-ft × 32-ft test chamber. The test chamber challenge aerosol was generated by atomizing liquid corn oil at room temperature using a Laskin nozzle. The Laskin nozzle produced a coarse aerosol cloud, which was directed into an impaction plate to remove the larger particles and yield an aerosol in the desired size range. The concentrated aerosol from the generator was diluted with filtered ambient air to control the challenge aerosol concentration in the exposure chamber.

A six-decade, 45° off-axis light-scattering laser photometer, sampling at a flow rate of 1 - 2 L/min, was used to quantify concentration of the challenge and the in-mask corn oil aerosols. For a given particle size, the quantity of scattered light is proportional to the aerosol concentration. The photometer converted the quantity of scattered light to a voltage, which was then digitized and recorded by a microcomputer.

The respirator sampling port was connected to the photometer with flexible silicone tubing to measure the amount of aerosol penetrating the mask. A Tygon® sampling tube line was connected from the exposure chamber sampling port to the photometer to determine the challenge aerosol concentration.

3.2 Test Procedure.

Each respirator was worn by military volunteers and challenged with the corn oil aerosol. Prior to testing, each test volunteer was given an orientation in which the PF test was explained by ECBC personnel and a volunteer agreement was signed by each test volunteer.

All volunteers had anthropometric measurements taken of their facial features, and then they were given a respirator and asked to wear their normal clothing (Battle Dress Uniform (BDU)). There were 30 volunteers who entered the facility, 24 were chosen to take part in the test according to their facial measurements, and 12 respirators were used for the test. The anthropometrical data can be found in the Appendix.

The CB40 respirator was expertly donned by ECBC personnel onto the volunteers. The subjects had no influence on the don, it was performed solely by ECBC personnel, followed by a successful negative pressure check. The test volunteers were then led into the aerosol exposure chamber, eight at a time, by ECBC personnel, hooked up to their

Table 3. Detailed PF Test Data

MASK	SUBJECT	TRIAL	PF_o	PF_i									
				1	2	3	4	5	6	7	8	9	10
CB 11 S	1	1	91,768.2	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	52,714.1	100,000
		2	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
CB 10 S	2	1	15,868.4	10,172.9	21,834.0	17,776.9	10,875.6	9,402.3	14,498.0	11,519.5	100,000	61,270.2	20,234.6
		2	224.8	94,539.2	62,810.1	73,763.5	69,303.9	17,306.5	53,555.5	100,000	100,000	25.0	227.3
CB 2 L	3	1	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
		2	74,382.8	100,000	100,000	100,000	100,000	100,000	22,502.5	100,000	100,000	100,000	100,000
CB 1 L	4	1	30,098.1	34,386.0	35,398.3	44,366.9	39,181.6	31,994.9	20,752.4	27,295.1	30,330.6	23,519.9	28,338.7
		2	24,860.6	32,711.3	19,485.3	18,016.0	27,770.3	33,507.6	16,413.1	27,896.0	31,227.2	28,174.2	28,817.9
CB 7 L	5	1	41,502.1	26,294.5	39,980.5	25,829.6	31,854.9	50,312.0	50,974.2	78,681.3	91,928.8	58,364.3	36,250.1
		2	83,200.5	61,107.4	100,000	46,383.1	100,000	100,000	81,517.2	100,000	100,000	100,000	100,000
CB 6 L	6	1	97,393.9	100,000	100,000	100,000	100,000	95,313.3	82,073.9	100,000	100,000	100,000	100,000
		2	99,973.5	100,000	100,000	100,000	100,000	99,735.7	100,000	100,000	100,000	100,000	100,000
CB 5 L	7	1	5,022.0	5,333.6	5,387.0	5,821.0	5,514.5	5,517.0	4,821.2	3,902.4	4,664.1	4,554.4	5,374.3
		2	4,834.4	5,098.7	5,669.9	5,430.5	4,329.8	4,592.5	4,661.6	4,288.5	4,743.1	4,933.9	4,951.9
CB 9 L	8	1	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
		2	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
CB11 S	9	1	11,533.6	42,441.5	25,139.0	52,877.3	99,814.8	86,516.1	100,000	85,558.4	100,000	1,952.3	4,560.1
		2	266.2	247.2	221.7	236.7	245.5	273.1	290.8	258.2	256.2	287.6	424.4
CB10 S	10	1	63,177.9	46,448.8	65,836.9	100,000	49,773.6	39,656.1	45,481.9	100,000	100,000	100,000	70,074.7
		2	26,490.9	10,080.4	25,919.4	21,667.6	11,825.7	23,272.7	40,257.1	100,000	100,000	95,159.3	93,702.5
CB4 L	11	1	64,112.5	100,000	100,000	100,000	100,000	100,000	15,157.1	100,000	100,000	100,000	100,000
		2	79,946.2	29,724.5	100,000	100,000	100,000	100,000	87,399.4	100,000	100,000	100,000	100,000
CB3 L	12	1	26,981.2	76,653.5	52,336.5	11,034.1	13,173.1	12,417.7	34,387.9	43,236.7	61,745.7	100,000	76,912.6
		2	46,689.9	68,095.6	72,971.0	44,369.2	36,094.1	36,696.4	68,766.3	23,510.7	33,706.7	86,565.4	100,000
CB8 L	13	1	98,134.3	100,000	100,000	100,000	100,000	100,000	84,025.8	100,000	100,000	100,000	100,000
		2	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
CB7 L	14	1	10,397.4	18,882.5	30,511.3	16,506.2	17,669.2	35,761.7	33,295.7	17,998.5	27,495.0	1,834.4	15,677.3
		2	3,165.4	100,000	100,000	49,006.2	100,000	77,478.0	100,000	100,000	100,000	327.2	100,000
CB6 L	15	1	68,311.4	100,000	100,000	100,000	100,000	100,000	100,000	96,897.2	17,835.4	100,000	100,000
		2	98,686.9	100,000	100,000	100,000	100,000	100,000	100,000	94,787.7	92,758.5	100,000	100,000

Table 3. Detailed PF Test Data (continued)

MASK	SUBJECT	TRIAL	PF_o	PF_1									
				1	2	3	4	5	6	7	8	9	10
CB9 L	16	1	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
		2	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
CB10 S	17	1	85,241.5	100,000	100,000	100,000	55,390.7	51,920.5	100,000	100,000	100,000	100,000	100,000
		2	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
CB11 S	18	1	83,770.9	100,000	100,000	100,000	100,000	100,000	34,044.7	100,000	100,000	100,000	100,000
		2	95,755.9	100,000	100,000	100,000	100,000	100,000	100,000	69,289.4	100,000	100,000	100,000
CB9 L	19	1	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
		2	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
CB5 L	20	1	6,859.6	6,998.6	7,141.2	6,620.2	7,090.9	6,339.5	6,660.8	6,964.9	7,384.8	6,721.6	6,794.5
		2	5,951.9	5,972.3	6,122.5	5,387.9	5,912.1	5,815.0	6,024.4	5,956.7	5,931.2	6,259.4	6,233.5
CB7 L	21	1	74,215.7	79,436.5	100,000	44,774.4	100,000	72,983.6	38,288.1	100,000	100,000	100,000	100,000
		2	91,835.6	100,000	100,000	100,000	100,000	100,000	52,937.4	100,000	100,000	100,000	100,000
CB4 L	22	1	88,413.6	100,000	100,000	100,000	100,000	72,221.4	100,000	100,000	100,000	51,925.3	100,000
		2	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000	100,000
CB8 L	23	1	91,515.9	100,000	100,000	100,000	100,000	51,892.4	100,000	100,000	100,000	100,000	100,000
		2	98,067.8	100,000	100,000	100,000	100,000	83,540.4	100,000	100,000	100,000	100,000	100,000
CB6 L	24	1	94,769.0	100,000	100,000	100,000	100,000	100,000	100,000	100,000	64,433.9	100,000	100,000
		2	99,387.5	100,000	100,000	100,000	100,000	100,000	100,000	94,195.0	100,000	100,000	100,000

photometer stations, and asked to perform a standard Army PF Test ("Joint Service Standardization Agreement for Fit Factor Testing of Military Masks", 10 Jan 1992) devised to stress the face seal of the respirator, namely the following 10 exercises for 1-min each:

1. Normal Breathing
2. Deep Breathing
3. Head Side to Side
4. Head Up and Down
5. Recite the "Rainbow Passage"
6. Sight the Rifle
7. Reach for the Floor and Ceiling
8. On Hands and Knees Look Left and Right
9. Facial Expressions
10. Normal Breathing

This process was performed six times, twice each for the three groups of eight, for a total of 48 data points. The minimum number of data points necessary is 22 to give a statistical validity or 90% reliability at a 90% confidence level. The test equipment operator monitored and audibly communicated with the test volunteers on when to start an exercise, finish an exercise, and exit the aerosol chamber. They also monitored the volunteers' performance. All exercises were completed by the test volunteers without the intervention of test personnel. All raw data were collected by a computer-based system and stored for later analysis.

3.3 Data Analysis.

Mask performance was quantified in terms of a PF. The PF was calculated by determining the ratio of the challenge aerosol concentration to the in-mask aerosol concentration as quantified by integrating the curve of the voltage output from the photometer over a time interval (nominally 1 min). A PF was calculated for each individual exercise (PF_i):

$$PF_i = \frac{Challenge\,Concentration}{In-mask\,Concentration}$$

Each PF_i for that trial was then used to calculate an overall PF for a subject (PF_o) as follows:

$$PF_o = n\left(\sum_{i=1}^{n}\frac{1}{PF_i}\right)^{-1}$$

where n is the number of exercises. The PF_o is affected most by the smallest PF_i. Under the conditions of this test and the sensitivity of the photometer, the maximum PF that can be reported is 100,000. A computer was used to calculate the PFs.

3.4 Protection Factor Test Results and Discussion.

The raw data is presented in Table 3. The PF_i is listed for each exercise as well as the PF_o for the entire trial. It can be seen that there were some leaky fits. For example, subject 9 got a PF of 11,000 in the first trial and only 266 in the next. In this case, the subject tested was too small even for the small mask, according to the manufacturer's sizing requirements. The leak is attributed to a gap in the facepiece due to poor sizing thus causing a bad fit. The small test subject did manage to obtain a good seal on the first trial, however. The mask involved, CB-11-S, was used several times during the test and was a good quality mask.

In another case, subject 2 had a good fit, with PF values well over 10,000, until exercise 9, the facial expressions, where the face seal seems to have been lost and not recovered for the final exercise, normal breathing. This example illustrates how strongly the lowest values of PF influence PF_0 according to the calculation method shown in Section 3.3.

4. SUMMARY

Twenty-two ITL/C2A1/FR canisters were tested against a concentration challenge of 200 mg/m^3 of Sarin (GB). The canisters were tested for 1 hr. None of the canisters showed any detectable penetration of GB. This indicates that the likelihood of a cartridge yielding detectable breakthrough is less than 10% at the 90% confidence level. These results are applicable only to GB.

Three CREATEC CB40 full face respirators with ITL/C2A1/FR canisters, mounted on the SMARTMAN headform, were tested against a concentration challenge of 200 mg/m^3 of GB. One of the respirators with canister was tested for a period of 1 hr; the other two were tested for 3 hr. No GB was detected inside any of the three respirator facepieces during the 1- or 3-hr test periods.

The CB40 respirator protection factor (PF) test was performed in accordance with the U.S. Army PF testing standard for NPRs used in a chemical - biological environment. Although these standards are not for commercial NPR respirators, they serve as a good comparison for the CB40 respirator. The pass percentages at selected PF levels for the CB40 are summarized in Table 4.

The first column lists each range of PF computed. The second column is the number of test trials falling within each calculated PF range. The third column presents the cumulative-percentage of test trials that resulted in a PF below the upper limit of the range and the fourth column presents the percentage of trials that exceed the lower limit of the range shown. The final PF range shown is over 100,000, but the current data acquisition system cannot measure PF over 100,000, so it truncates the data and puts all the remaining subjects in the final range. Table 4 shows that 95.83% of all trials achieved a PF of at least 2,000, and 85.42% achieved a PF of at least 10,000.

Table 4. PF Results from CB40 Respirator

PF Range	No. of Occasions in Range	Cumulative Rate, Percent	Cumulative Pass Rate, Percent
0-9	0	0.00	100.00
10-19	0	0.00	100.00
20-49	0	0.00	100.00
50-99	0	0.00	100.00
100-499	0	0.00	100.00
500-999	2	4.17	95.83
1000-1666	0	4.17	95.83
1667-1999	0	4.17	95.83
2000-6666	0	4.17	95.83
6667-9999	4	12.50	87.50
10000-19999	1	14.58	85.42
20000-49999	3	20.83	79.17
50000-999999	6	33.33	66.67
100000(+)	32	100.00	0.00
No. of Trials	48		

Blank

GLOSSARY

Air-Purifying Respirator (APR)

These respirators contain an air-purifying filter, cartridge, or canister that removes specific contaminants by passing ambient air through the air-purifying element. These do not supply oxygen and must be used only when there is sufficient oxygen to sustain life. In addition, these cartridge/canisters usually do not include an end-of-service life indicator (ESLI) to warn the respirator user of the approach of the end of adequate respiratory protection.

Breather Pump

A pump used to simulate human breathing through a filter. The pump is a piston pump designed to begin the stroke at zero flow, rise to a maximum (peak) flow at midstroke, and decrease to zero at the end of the stroke. The resultant flow is sinusoidal, that is, shaped like a sine wave. The pump stroke can be adjusted to change the volume of air per stroke over a finite range; some pumps are capable of changing the number of strokes per minute.

Canister (Air-Purifying)

A container filled with sorbents, catalysts and filters that removes gases, vapors, and/or particulates from air drawn through the unit. Canisters rely on a variety of mechanisms for contaminant removal such as chemical absorption, adsorption, catalytic action, neutralization, and mechanical filtration.

Cartridge

A container filled with sorbents, catalysts, and filters that removes gases, vapors, and/or particulates from air drawn through the unit. Cartridges are smaller than canisters (<150 ml volume) but are designed to work on the same principles.

DoD

Department of Defense

ECBC

Edgewood Chemical Biological Center

Exhalation Valve

A device that allows exhaled air to leave a respiratory device and prevents outside air from entering through the valve while inhaling.

Facepiece

The portion of a respirator that covers the wearer's nose and mouth (a full facepiece also covers the eyes). The facepiece should make a gas-tight or dust-tight seal with the face. The facepiece is supported by headbands, and contains inhalation valves, exhalation valves, and connectors for the air-purifying cartridges or filters.

Filter

An air-purifying element used in respirators to remove solid or liquid particulates from the air before it enters the facepiece (this term may be used interchangeably with cartridge).

Fit Factor (FF)

A Fit Factor is a number that is the direct result of a quantitative respirator fit test. It is a measurement made by an instrument during a simulation of workplace activities or scenarios. It is expressed as the challenge aerosol concentration outside the respirator divided by the challenge aerosol concentration that leaks inside the respirator during a Fit Test.

NPR, Negative Pressure Respirator, tight fitting

This is a respirator that fits tightly to the face; it has a negative (lower) air pressure inside the facepiece with respect to ambient air pressure outside the respirator during inhalation.

SBCCOM

Soldier and Biological Chemical Command

Inhalation Valve

A device that allows air to enter the facepiece through the filtering media but prevents exhaled air from leaving the facepiece through the intake openings.

MINICAMS®

Trade name for a chemical agent detector in which the agent is adsorbed from a specified volume of air onto an adsorbent tube which is then desorbed into the injection port of a gas chromatograph for analysis (quantitation). The acronym stands for "Miniature Continuous Air Monitoring System."

Particulate Matter

A suspension of fine solid or liquid particles in air, i.e., dust, fog, fume, smoke, or sprays. Particulate matter suspended in air is commonly known as an aerosol.

Protection Factor

The overall protection afforded by a certain type of respirator as defined by the ratio of the concentration of contaminant outside a facemask or hood to that inside the mask while in a contaminated atmosphere. The protection factor as used in this report is the overall factor calculated from individual fit factors determined on a number of human volunteers for each of several exercises performed while wearing the respirator.

Sarin

An organophosphorus nerve agent, known by the military symbol GB. The chemical name is isopropyl methylphosphonofluoridate. GB reacts with the enzyme cholinesterase, thus interfering with the transmission of nerve impulses.

Blank

APPENDIX

ANTHROPOMETRICAL DATA

The following table shows each subject in the protection factor test and their respective facial measurements, along with the mask size assigned. Face length is known as the menton nasion and the face width is also known as the bizygomatic breadth.

Subject		Face	
	Mask Size	Length (mm)	Width (mm)
1	Small	126.0	143.0
2	Small	126.0	139.0
3	Large	119.0	141.0
4	Large	120.0	141.0
5	Large	126.0	149.0
6	Large	134.0	137.0
7	Large	122.0	140.0
8	Large	123.0	142.0
9	Small	113.0	144.0
10	Small	123.0	135.0
11	Large	122.0	151.0
12	Large	124.0	138.0
13	Large	110.0	141.0
14	Large	123.0	137.0
15	Large	129.0	136.0
16	Large	124.0	139.0
17	Small	119.0	140.0
18	Small	131.0	140.0
19	Large	138.0	150.0
20	Large	134.0	151.0
21	Large	114.0	139.0
22	Large	123.0	137.0
23	Large	131.0	137.0
24	Large	123.0	136.0

DEPARTMENT OF THE ARMY
CDR USARDECOM
ATTN AMSRD CII
5183 BLACKHAWK ROAD
APG MD 21010-5424

OFFICIAL BUSINESS

FIRST CLASS

DEFENSE TECHNICAL INFORMATION CENTER
ATTN DTIC OCA (ACQUISITIONS) J CHIRAS 1
8725 JOHN J KINGMAN ROAD SUITE 0944
FT BELVOIR VA 22060-6218